O5 GMI - Graphics & Medical Imaging

2019 Module Description

Topic:	eHealth Eurocampus
Module Name and Code:	O5 Graphics & Medical Imaging (GMI-111)
Place:	Barcelona, Spain
Date:	1-12 July 2019
Coordinator:	Christos P Loizou (christos.loizou@cut.ac.cy)
Teaching Language:	English
Level/Teaching Hrs:	MSc, 6 ECTS (*80 hrs in class and 70 hrs at home*). *Module Duration total hours = 150 student hrs.*
Delivery Method:	Theoretical and practical units with 2-3 real case projects from the real medical practice
Prerequisites:	Digital Signal Processing or Signals & Systems, Basic Programming skills (Not advanced programming is required). Students finished their r bachelor's degree or in MSc course.

Course description and general objectives:

This module will be delivered in three different parts and will cover, 1) fundamentals of imaging modalities and the fundamental components of medical image analysis and visualisation, 2) virtual environments and advanced computer graphics and 3) game design and serious games involved. It will develop skills (graphics) that make students operative regarding health applications to cope with physical and cognitive disabilities. The course will cover basic knowhow, and technologies involved in the development of virtual environments and serious games immersed with medical image and video content. Once the student has completed this module he/she will be able to analyse problems in the medical domain, extract the needs and requirements and proceed with the design, development, and implementation of the virtual environment of serious game needed. Here the focus is on medical image and video analysis with lab support which is based on software downloaded from the web (freeware).

The course will start with an introduction to the underlying concepts and mathematics of biomedical image processing including data storage types and co-ordinate systems. This will be followed by the low-level image processing techniques of quality control, intensity correction, image filtering, segmentation and image analysis. The course will enable you to: identify major processes involved in the formation of medical images, recognize the imaging modality from their visualization, classify the various medical image processing algorithms, describe fundamental methods of image enhancement, enhance medical images using appropriate software, visualize all types of medical image data, appraise efficacy and drawbacks of several techniques of image segmentation and get familiar with the fundamental concepts of texture analysis and segmentation. Get started with OpenCV and self-perform fundamentals of medical image processing and involved with the development of virtual environments and advanced computer graphics. Furthermore, the course will provide the fundamentals of gamification, serious games and gamifications for health examples, serious games design process and game development tools. The remainder of the course will focus on specific examples and practical applications in form of projects where medical image/video processing systems will be developed which can be used in the medical practice. In addition to this theoretical background, students will be expected to work through real data examples using common image analysis tools.

Learning outcomes:

After taking this course the participants will have a basic understanding in the following areas:

- Knowledge of basic principles for medical imaging based using advanced image modalities: MRI, CT, Ultrasound and PET-CT
- Knowledge of data analysis, image processing and post processing techniques for the different modalities
- Knowledge of technological similarities and differences between the different modalities and choice of equipment for different clinical applications
- Knowledge of ionizing radiation related risks and radiation protection principles in medical imaging
- Knowledge of new applications and technology trends for the different modalities
- Knowledge on virtual environments and advanced computer graphics
- Game design, fundamentals of gamification, serious games and gamifications for health examples, Serious games design process and game development tools
- Knowledge on how to analyze and assess a scientific article

Prerequisites: None

Teaching Methods: This module comprises as set of Microsoft Powerpoint presentations, all of which have teacher's guidance notes in the Notes sections of the presentations. Lectures (i.e. teaching-T) and Labs (L) will be taken in class and will include 80 ECTS hours. Another 70 ECTS hours will be taken by students at home (H) for preparing projects, exercises and will be used as additional study time. The total study time of the course including T, L and H will include 150 hrs.
We consider a regular master course, for instance, one semester course, 18-20 weeks at 4 or 5 lecture-lab hours per week and a ratio of 80 hours in class and 70 hours of personal work. No instructions about assessments are included.

Assessment: There are assessments in form of labs and work that has to be done at home They cover group projects work to develop image/video software processing systems.

Course Content:

Week	***Topic***	T/L/H	StudyTime	Partner
	PART I: Graphics & Medical Imaging			
1	***Chapter 1: Introduction to Medical Imaging***: Imaging introduction, X-ray imaging, Computed tomography, Magnetic resonance Imaging (MRI), Nuclear Medicine (PET, SPECT), Nuclear imaging, Ultrasound Imaging, Magnetic resonance imaging. (seven different presentations and two LABS)	T/L/H	4/-/4	UIB
	Examples from Medical applications		3/2/3	FSJD
2	***Chapter 2: Binary Image Processing & Point Operations: Binary Image & Point Operations (Medical image processing & analysis):*** Binary images and morphology, histograms, Histogram matching, logarithmic compression, gamma correction, arithmetic & geometric image operations. Examples from medical applications. Display one-, two, and 3D images. Medical imaging modalities and acquisition systems, image management. (**Two different presentations and one** LAB) ***Computer Group Project on Medical Imaging & Video***	T/L/H	3/2/4	UIB
3	***Chapter 3: Fourier Transform:*** Goals of the course, Linear shift invariant systems, convolution concepts & properties, sinusoidal images, Discrete Fourier transform, meaning of image frequencies, sampling theorem, MRI and the Fourier Transform, FFT examples on medical applications. (**Lab on FFT**)	T/L/H	2/1/4	UCY
4	***Chapter 4: Linear Image & Filtering***: Image filtering, types, linear image filters, Correlation vs convolution, Linear vs non-linear filtering, Smoothing vs sharpening, Linear filtering and discrete convolution, mean filter, Gaussian Filtering, Derivative filters, Laplacian Wiener, Moving average, Low-, Band-, high-pass filtering, Linear Image Denoising Examples from medical applications in diagnostic imaging. **Lab on Linear Image Filtering.**	T/L/H	4/-/4	UCY
5	***Chapter 5: Non-Linear Image Filtering***: Non-linear filtering concept, Filtering Applications, Median and median-weighted filtering, Min, Max (Rank order filters), morphological filtering, Conditional Mean, Entropy, Kuwahara, Bilateral Filtering, Image Noise Models, Morphological Filters, Homomorphic Filter, Anisotropic diffusion, Wavelet Thresholding. **Lab on non-Linear Image Filtering.**	T/L/H	3/2/5	UCY
	Case studies on some recent advances in analysis of retinal, CT, MRI, ultrasound and histology images	T/L/H	-/-/7	UCY
6	***Chapter 6: Image quality and evaluation metrics:*** Image quality metrics, MSE, PSNR, SSIM, SQI, Examples from medical applications. Diagnostic imaging. **Lab on image quality and evaluation.**	T/L/H	3/2/3	UCY
7	***Chapter 7: Medical Image segmentation, analysis and 3D reconstruction***: Segmentation overview, Medical Image Analysis Systems, Medical image segmentation & analysis, Medical image segmentation methods: Deformable Models, Markov Random Fields Level sets, Texture Analysis revisited. 3D Reconstruction principles and examples. **Lab on image segmentation.**	T/L/H	3/2/3	FSJD

	PART II: Virtual Environments & Advanced Computer Graphics			
8	**Virtual Reality & Computer Graphics – Introduction.** Basic concepts, continuum from Reality to Virtual Reality (augmented, mixed reality), Historical background, VR applications, vr libraries, 3D modeling, geometry of virtual worlds (translation, rotations, orientation through matrix transformations), scene graph, view and projection transformations, rendering pipeline.	T/L/H	3/3/4	UM
9	**Image Rendering**. Rendering the virtual environment, properties of light, local illumination models (Gouraud, Phong), shadows, global illumination models (raytracing, radiosity), textures	T/L/H	3/3/4	UM
10	**Interaction**. Basic 3D Interaction Tasks and Techniques, Selection & manipulation, navigation, system control, Overview of VR hardware (display, tracking, haptics, input/output), human factors.	T/L/H	3/3/4	UM
11	**Animation**. Motion and physics of VR worlds, animation methods (inverse and direct kinematics, particle systems, motion capture).	T/L/H	3/3/5	UM
	Case studies on some recent advances in virtual environments and computer graphics	T/L/H	-/-/-	UM
	PART III: Game Design			
12	***Fundamentals of Gamification:*** Games fundamentals, narrative structure, interaction, game design elements, Motivation factors, Ethical considerations.	T/L/H	3/1/4	UPC
13	***Serious games and gamifications for health examples:*** Cognitive rehabilitation, functional rehabilitation, screening, assessment and patient's data collection.	T/L/H	3/2/4	UPC
14	***Serious games design process***: Roles involved in the process, the dominium expert, steps of development, assessment and validation.	T/L/H	3/2/4	UPC
15	**Game development tools.** Game engines, storytelling tools.	T/L/H	3/3/4	
	Computer Group Project on Medical Imaging & Video	T/L/H	-/-/-	
	REVISION			
	TOTAL ECTS (6) HOURS (150)	T/L/H	49/31/70	

L: Lecture (Theory in class), L: Lab (Practice in class), H: Home (Practice at home), UCY: University of Cyprus, UPC: University Polytechnical Catalunya Barcelona, UM: University of Montpelier, UIB: University of Balearic Islands.

Book Learning resources:

Online Books that can be downloaded for free:

1. Isaac N.Backman, Handbook of Medical Imaging, Processing and Analysis, Academic Press., 2000, ISBN: 0001020304COB987654321 (Available on line: http://library.nuft.edu.ua/ebook/file/Bankmadbook%20Medies2000.pdf)
2. J. G. Webster, E. R. Ritenour, S. Tabakov, K.-H. Ng, Wbb's Physics of medical imaging, CRC press, Taylor & Francis group, 2012. (Available on line: https://paramedfac.tbzmed.ac.ir/uploads/User/28/pira/%DA%A9%D8%AA%D8%A8%20%D9%81%DB%8C%D8%B2%DB%8C%DA%A9%20%D9%BE%D8%B2%D8%B4%DA%A9%DB%8C/Webb_s_Physics_of_Medical_Imagi_-_Flower__M_A.pdf).

3. W. R. Hendee, E. R. Ritenour, Medical Imaging Physics, 4rth Ed., John Wiley & Sons, 2002. (Available on line: https://www.zuj.edu.jo/download/medical-imaging-physics-fourth-edition-wiley-pdf/).
4. M. Y. M. Chen, T. L. Pope, D. Ott, Basic Radiology, 2nd Ed., Mc Graw Hill, 20011. ISBN: 978-0-07-176664-7. (Available on line: https://paramedfac.tbzmed.ac.ir/uploads/User/28/pira/%DA%A9%D8%AA%D8%A8%20%D9%81%DB%8C%D8%B2%DB%8C%DA%A9%20%D9%BE%D8%B2%D8%B4%DA%A9%DB%8C/LANGE%20Basic%20Radiology%20by%20Michael%20Y.%20M.%20Chen,%20Thomas%20L.%20Pope,%20David%20J.%20Ott%202nd%20Edition%202010.pdf)

Other recommended Books:

5. Medical Imaging Signals and Systems by J. L. Prince and J. M. Links, Pearson, Prentice Hall, 2006, ISBN 0130653535.
6. Fundamentals of medical imaging, Paul Suetens, 2nd Ed., Sept. 2009, ISBN: 9780511596803.
7. Medical Imaging Signals and Systems, J. L. Prince, J. Links, 2nd Ed., Pearson, ISBN-10: 0132145189.
8. *Webb's Physics of Medical Imaging*. M. A. Flower (Editor) CRC Press, Taylor & Francis Group, 2012. ISBN: 978-0-7503-0573-0.

These books contain information on the material covered and may be help clarify the issues discussed in class and as references for related information. Their reading is not mandatory, but reference to them is recommended.

Lecturer's Policy:

Attendance is required. Those absent for more than 20% of the course will be automatically withdrawn without any further notice, unless a valid excuse is presented (a doctor's note may not be sufficient). Students absent or late for classes are responsible for material covered or announcements made during sessions missed.

Cheating, like plagiarism, undermines the academic spirit. Consequently, it will not be tolerated. Students guilty of cheating or plagiarism will receive a zero ('0') on the course work or test concerned and may face further disciplinary action.

Make-up exams are **not** an option. They are permitted under exceptional circumstances and only if Universities policy is not violated. Thus, you are advised not to miss any exams or tests. Students who miss an exam or a test and are not granted permission to sit for a make-up will receive a zero ('0') for that particular test. If you have a valid reason for missing the exam, please inform the Lecturer in advance.

Recommended readings are listed on your course outline. Do take the time to peruse through these readings (and websites). They will enhance your knowledge on the subject, particularly if you are pursuing the grade 'A' in the course. Also, additional readings will enable you to take a more active and constructive role in class discussion.

Mobile phones **MUST** be muted and removed from the desk when class is in session and during exams. Please respect the time and efforts of the lecturer and other students.

Thank you for your cooperation.